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(56) Documents Cited
GB 2307311 A EP 0972927 A2 EP 0950801 A1
EP 0928890 A1 US 5778666 A US 5771685 A
US 5693877 A US 5317868 A

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UK CL (Edition R) B1W WAX WD WX
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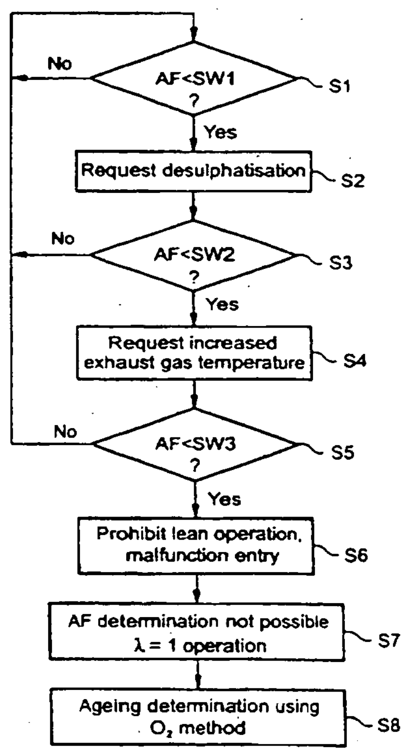
(54) Abstract Title

Monitoring diminished NOx trap performance

(57) The ageing status of the NOx storage catalytic converter is expressed by means of an ageing factor (AF) which describes the current storage capacity of the NOx storage catalytic converter after it has been reduced by ageing influences. The ageing factor (AF) is compared in succession with multiple threshold values (SW1-SW3) of differing levels, where the level of the threshold values (SW1-SW3) decreases as the flow distance of the NOx storage catalytic converter increases. In the event of certain threshold values (SW1 - SW3) not being reached, different operational strategies are initiated for the NOx storage catalytic converter and/or the internal combustion engine, e.g: a sulphur purge.

FIG 2



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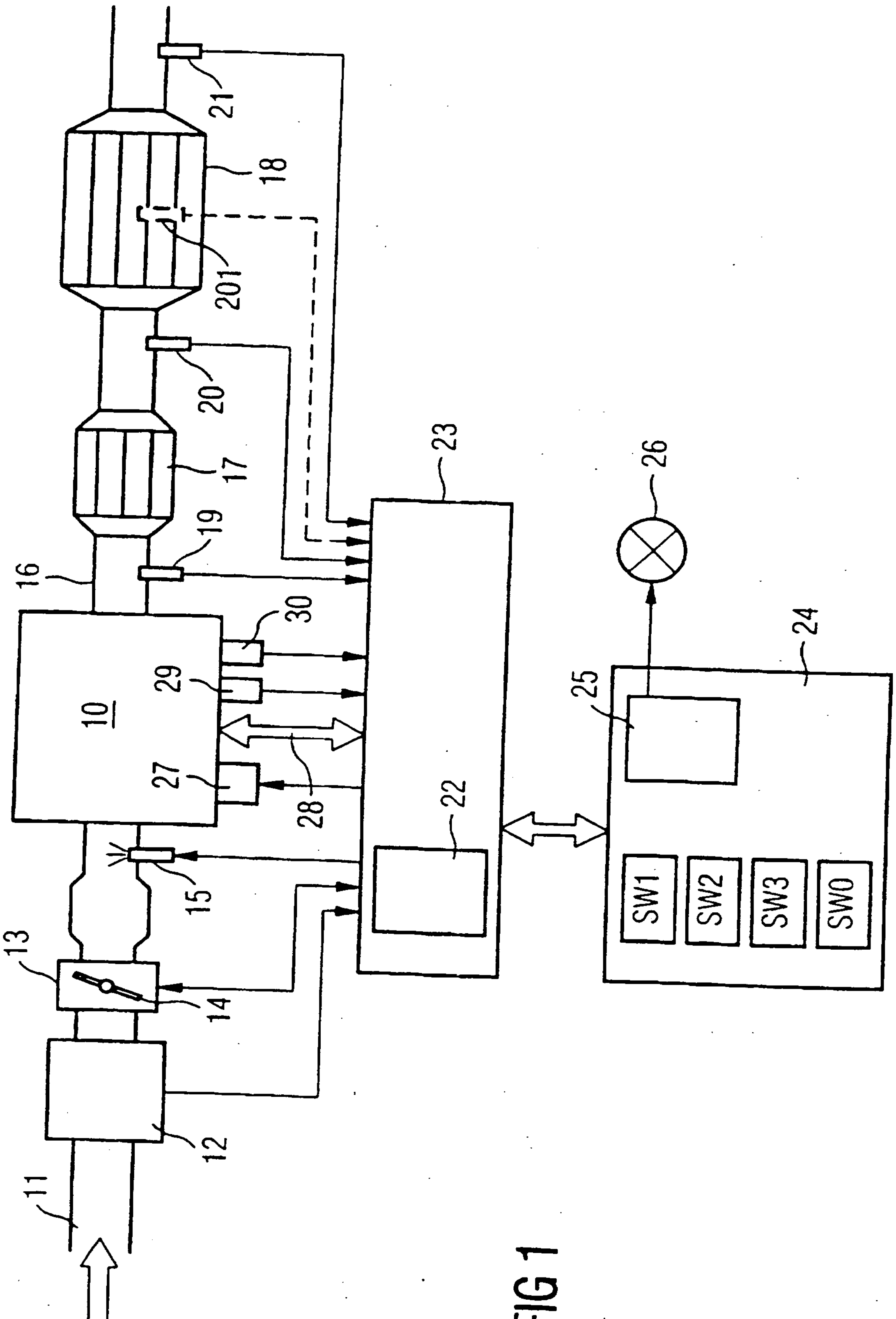
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


10
11
12
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16
17
18
19
20
201
21
22
23
24
25
26
27
28
29
30
SW1
SW2
SW3
SW0

FIG 1

FIG 2

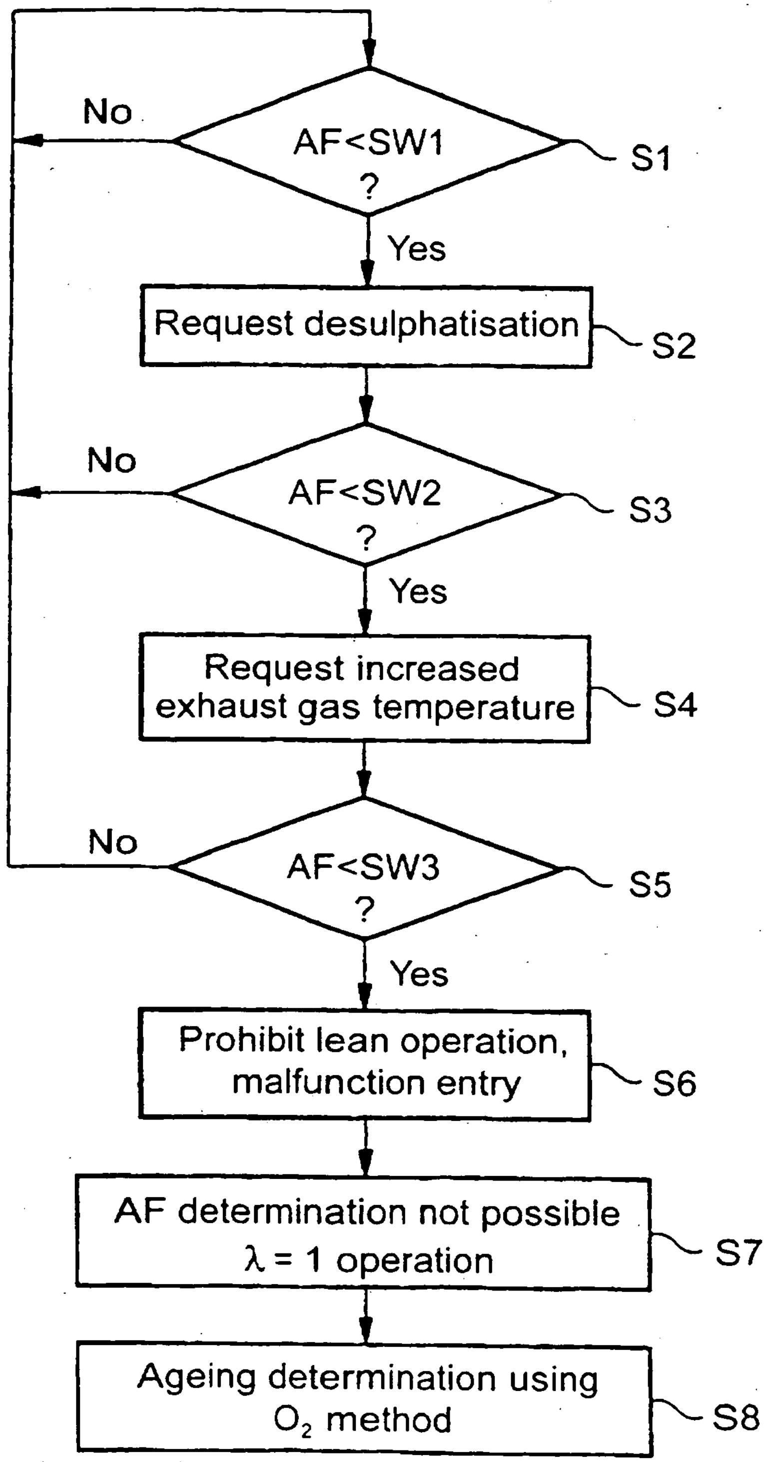

AF<SW1
?
No
Yes
S1
Request desulphatisation
S2
AF<SW2
?
No
Yes
S3
Request increased exhaust gas temperature
S4
AF<SW3
?
No
Yes
S5
Prohibit lean operation, malfunction entry
S6
AF determination not possible
$\lambda = 1$ operation
S7
Ageing determination using O_2 method
S8

FIG 3

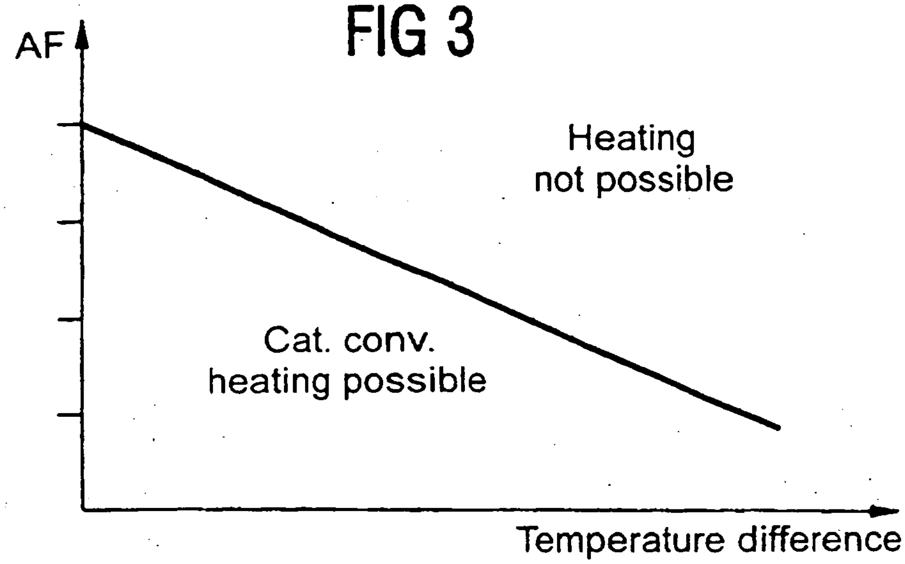
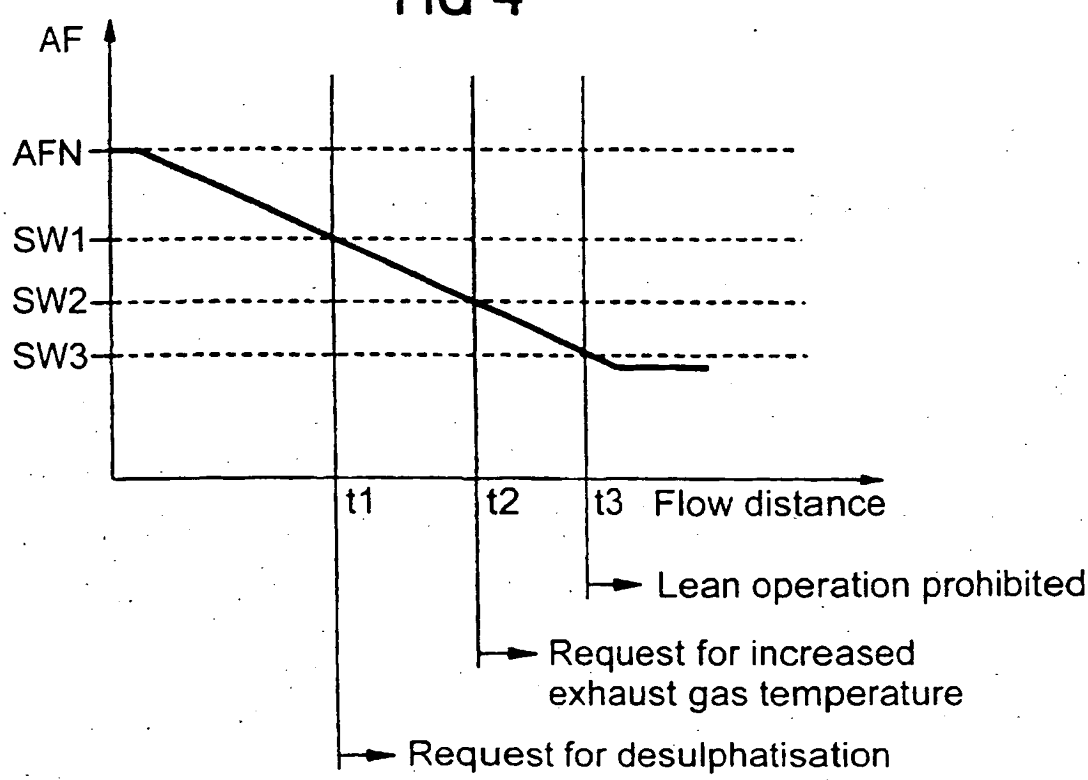

AF
Heating
not possible
Cat. conv.
heating possible
Temperature difference

FIG 4


AF
AFN
SW1
SW2
SW3
t1
t2
t3
Flow distance
Lean operation prohibited
Request for increased
exhaust gas temperature
Request for desulphatisation

2344771

Description

Method for operating and checking of a NOx storage reduction catalytic converter for a lean internal combustion engine

The invention relates to a method for the operation and checking of a NOx storage reduction catalytic converter for a lean internal combustion engine in accordance with the pre-characterising clause of Claim 1.

In order to further reduce the fuel consumption of motor vehicles powered by an internal combustion engine, increasingly frequent use is made of internal combustion engines which are operated with a lean mixture at least in selected operating ranges.

In order to meet exhaust gas emission limit value requirements, special exhaust gas secondary treatment is needed for lean internal combustion engines of this type. NOx storage reduction catalytic converters, referred to simply as NOx storage catalytic converters in the following, are used for this purpose.

By virtue of their coating, these NOx storage catalytic converters are able during a storage phase, also referred to as a loading phase, to adsorb NOx compounds from the exhaust gas produced during lean combustion. During a regeneration phase the adsorbed, or stored, NOx compounds are converted into harmless compounds through the addition of a reducing agent. CO, H_2 and HC (hydrocarbons) can be used as the reducing agent for lean internal combustion engines. These are produced by operating the internal combustion engine for a short period with a rich mixture and are made available to the NOx storage catalytic converter in the form of exhaust gas components, as a consequence of which the stored NOx compounds are broken down in the catalytic converter.

NOx storage catalytic converters of this type are therefore loaded and unloaded in cyclical fashion, where the extent of the loading process is limited by the storage capacity of the NOx storage catalytic converter. This storage capacity is subject to degradation over the operational life of the internal combustion engine as a result of a wide range of influencing factors such as thermal ageing or sulphurisation.

If the current storage capacity of the catalytic converter is ascertained in an appropriate manner, this information can be used to provide optimum adjustment of control facilities for the catalytic converter (e.g. duration of the storage and regeneration phases, initiation of a desulphatisation phase, transition to stoichiometric motor operation) with regard to emission behaviour and fuel consumption and also, if necessary, to provide a malfunction indication with regard to the operability of the exhaust gas system.

The object of the invention is therefore to set down a method which offers the best possible means of control and assessment with regard to the activity of the NOx storage catalytic converter whilst taking into consideration the ageing status of the NOx storage catalytic converter.

This object is achieved by the features described in Claim 1. Useful further embodiments of the invention are set down in the subclaims.

The current storage capacity of the NOx storage catalytic converter is calculated from the stored quantity of NOx and the associated loading level of the NOx storage catalytic converter, using the signal from a sensor, located downstream of the NOx storage catalytic converter, which is capable of determining the concentration of at least one exhaust gas component. This

allows an ageing factor for the NOx storage catalytic converter to be derived which defines the current storage capacity of the NOx storage catalytic converter after it has been reduced by external influences. The ageing factor is compared in succession with multiple threshold values of differing levels, where the level of the threshold values decreases as the flow distance of the NOx storage catalytic converter increases. In the event of certain threshold values not being reached, different operational strategies are initiated for the NOx storage catalytic converter and/or the internal combustion engine.

One advantage of using this strategy is that the converter does not need to be replaced when its NOx storage capacity has fallen irreversibly below a minimum value; instead, the operational mode of the internal combustion engine is adapted to the status of the NOx storage catalytic converter.

A further advantage is that when desulphatisation of the NOx storage catalytic converter has been activated, the calculation of the storage capacity increment takes into consideration the dependency on the current value of the ageing factor along with the dependency on the converter temperature and the current air/fuel ratio.

The invention will be described in the following with reference to the drawing. In the drawing:

Figure 1 shows a schematic representation of an internal combustion engine with a NOx exhaust gas secondary treatment system,

Figure 2 shows a flowchart enabling evaluation of the ageing factor,

Figure 3 shows a diagram illustrating the progression of the ageing factor in relation to the flow distance of the NOx storage catalytic converter, and

Figure 4 shows a diagram illustrating the progression of the ageing factor over the flow distance and the operational strategy derived from this during lean operation of the internal combustion engine.

In the form of a block diagram, Fig. 1 illustrates a lean internal combustion engine with a NOx exhaust gas secondary treatment system in which the method according to the invention is applied. The diagram shows only the components which are required to understand the invention.

An air/fuel mixture is fed to the lean internal combustion engine 10 by way of an induction port 11. Viewed in the direction of flow of the intake air, the induction port 11 contains, in sequence, a load sensor in the form of an air mass meter 12, a throttle-valve block 13 with a throttle valve 14 and a throttle-valve sensor (not shown) for determining the angle of opening of the throttle valve 14 and, according to the number of cylinders, a set of injection valves 15, of which only one is shown. The method according to the invention can, however, also be used in a system in which the fuel is injected directly into the cylinders in question (direct injection).

On the outlet side, the internal combustion engine 10 is connected to an exhaust gas port 16. This exhaust gas port 16 contains an exhaust gas secondary treatment system for lean exhaust gas. This system consists of a pre-catalytic converter 17 (three-way catalytic converter) located close to the internal combustion engine 10, and a NOx storage reduction catalytic converter 18 referred to simply as a NOx storage catalytic converter in the

following, which is located after the pre-catalytic converter 17 in the exhaust gas flow direction.

The sensor system for the exhaust gas secondary treatment system consists of an oxygen sensor 19 upstream of the pre-catalytic converter 17, a temperature sensor 20 in the connecting pipe between pre-catalytic converter 17 and NOx storage catalytic converter 18 close to the inlet area of the latter, and a further oxygen sensor 21 downstream of the NOx storage catalytic converter 18. Instead of the temperature sensor 20, which measures the exhaust gas temperature and whose signal can be used to calculate the temperature of the NOx storage catalytic converter 18 on the basis of a temperature model, it is also possible to measure the NOx storage catalytic converter temperature directly. In Fig. 1, a temperature sensor 201 of this type which directly measures the monolithic temperature of the NOx storage catalytic converter 18 has been drawn with a broken line.

The calculation or measurement of the temperature of the NOx storage catalytic converter 18 is required in order to optimise fuel consumption control and exhaust gas emission control for the system. Catalytic converter heating or catalytic converter protection measures are also initiated or prohibited on the basis of this temperature signal.

By preference, a broadband lambda probe is used for the oxygen sensor 19 which provides a steady, e.g. linear output signal depending on the oxygen content in the exhaust gas. The signal provided by this broadband lambda probe serves to control the air ratio during lean operation and during the regeneration phase with a rich mixture in accordance with the predetermined desired values. This function is handled by an already familiar lambda

regulation device 22 which is by preference integrated into a control unit 23 controlling the operation of the internal combustion engine 10.

Such electronic control facilities which normally contain a microprocessor and which in addition to fuel injection and ignition also handle a large number of other control and regulation functions including control of the exhaust gas secondary treatment system are already known; therefore, their structure and mode of operation are described in the following only to the extent that is relevant to the invention. In particular, the control unit 23 is connected to a memory unit 24 which serves to store information including various characteristic curves and fields, and threshold values SW1-SW3, SW0, the respective meanings of which are explained in detail in the descriptions of the following figures. The memory unit additionally incorporates a malfunction memory 25 which has an associated malfunction indicator device 26. By preference, the malfunction indicator device 26 is implemented in the form of a malfunction indication lamp (MIL).

A temperature sensor 29 registers a signal corresponding to the temperature of the internal combustion engine, for example through measurement of the coolant temperature. The rotational speed of the internal combustion engine is registered by means of a sensor 30 which scans markings on the crankshaft or a transmitter wheel connected to the crankshaft.

The output signal from the air mass meter 12 and the signals from the throttle-valve sensor, the oxygen sensors 19, 21, the temperature sensors 20, 29, and the rotational speed sensor 30 are fed to the control unit 23 by way of corresponding connecting leads.

For controlling and regulating the internal combustion engine 10, apart from being connected to an ignition unit 27 for the air/fuel mixture, the control unit 23 is also connected by way of a data and control line 28 (shown only in schematic form) to other sensors and actuators which are not shown explicitly.

For regulating the fuel/air mixture of the internal combustion engine in the optimum lambda window during stoichiometric operation, the signal from the oxygen sensor 21 located as a reference probe downstream of the NOx storage catalytic converter 18 is required. A zirconium oxide ZrO_2 based binary lambda probe (2-point lambda probe), for example, can be used for the oxygen sensor 21; this probe exhibits a step characteristic at a lambda value of $\lambda=1$ with regard to its output signal. This probe signal from the lambda probe located downstream of the NOx storage catalytic converter 18 is also used for controlling the storage regeneration and for adapting model variables such as the oxygen storage capacity or NOx storage capacity of the NOx storage catalytic converter 18, for example, and for registering the ageing status of the NOx storage catalytic converter 18.

Instead of a binary lambda probe, any sensor whose output signal allows a conclusion to be drawn regarding a switch from a lean to a rich exhaust gas mixture composition, or vice versa, downstream of the NOx storage catalytic converter 18. In particular, an HC sensor or a NOx sensor can be used.

The ageing status of the NOx storage catalytic converter 18 is registered by means of the sensor 21 located downstream of the NOx storage catalytic converter 18, through evaluation of its output signal.

The ageing status of the NOx storage catalytic converter should be expressed by means of an ageing factor. This ageing factor describes the current storage

capacity of the NOx storage catalytic converter after it has been reduced by ageing influences. It registers deterioration in the storage capacity resulting both from sulphate formation caused by the sulphur contained in the fuel and from ageing effects. It is assumed for the other versions that a high value for this ageing factor corresponds to an as-new converter, while a low value for this ageing factor corresponds to a NOx storage catalytic converter in an ageing condition. However, it is also possible for the scale to be reversed.

In German patent application P 198 23 921.1 filed by the same applicant, a method is described which makes it possible to determine the current storage capacity of the NOx storage catalytic converter both from the signals from an oxygen sensor located downstream of a NOx storage catalytic converter and also from a NOx sensor, and allows conclusions to be drawn on the efficacy and operability of the converter.

On the basis of the flowchart in Fig. 2, the method explains how the ageing factor AF is evaluated to provide control and diagnostic facilities for the NOx storage catalytic converter 18.

In the first method step S1, a check is performed to determine whether the ageing factor AF falls below a first threshold value SW1. If this is the case, a desulphatisation phase is requested in step S2; otherwise, the method branches back to step 1. If this desulphatisation phase cannot be implemented, e.g. because the temperature level required for desulphatisation is not reached by the NOx storage catalytic converter 18, and the ageing factor AF continues to fall, then on failure to reach a further threshold value SW2 (interrogated in step S3) needed to attain the temperature level required for desulphatisation, an increase in exhaust gas temperature is requested (step S4), e.g. by retarding the ignition angle or by means of double injection. In this way it is possible to

attain the temperature level required for initiation of a desulphatisation phase even when the load on the internal combustion engine is low.

The temperature of the NOx storage catalytic converter at the time when an exhaust gas temperature increase is activated (outlet temperature level) is, in addition to being dependent on the temperature level for the NOx storage catalytic converter required for the desulphatisation operations, also dependent on the temperature difference which needs to be bridged in order to attain a temperature level needed for the desulphatisation operations, and on the current value of the ageing factor. The further the value of the ageing factor AF falls, the higher is the permissible temperature difference to be bridged. This relationship is represented in the form of the graph in Fig. 3.

If it is not even possible to attain the outlet temperature level reduced in this way and if the ageing factor AF continues to fall, then on failure to reach a third threshold value SW3 (interrogated in method step S5) lean operation of the internal combustion engine is prohibited and the NOx storage capacity of the NOx storage catalytic converter 18 then no longer comes into play.

From this point in time the NOx storage catalytic converter 18 is operated as a conventional three-way catalytic converter and a malfunction entry is made in the malfunction memory 25 (method step S6). The central malfunction indication lamp is not illuminated. The malfunction memory can be read out by means of suitable tools. Alternatively, the vehicle can then be operated with an air ratio of lambda=1 or the NOx storage catalytic converter 18 can be replaced.

If the motor vehicle continues to be operated with a stoichiometric mixture corresponding to an air ratio of lambda=1, the NOx storage catalytic converter

18 continues to age and the oxygen storage capability of the NOx storage catalytic converter 18 continues to fall.

This oxygen storage capability can be diagnosed by means of known diagnostic methods (method step S8). One method of checking the oxygen storage capability and thus the three-way properties of the NOx storage catalytic converter 18 consists, for example, in evaluating the output signals from the sensors located upstream and downstream of the NOx storage catalytic converter (DE 41 40 618 A1). If the oxygen storage capability falls below a prespecified minimum permissible threshold value SW0, then the NOx storage catalytic converter 18 is considered to be no longer operable and it must be replaced. In this case, the malfunction indication lamp 26 is illuminated.

If the attainment of the temperature level required in order to initiate desulphatisation is detected and if desulphatisation is requested, a desulphatising atmosphere is created in the NOx storage catalytic converter 18 by means of appropriate measures, for example by further increasing the exhaust gas temperature or by appropriate setting of the air/fuel ratio.

If a desulphatising atmosphere is detected, the value for the ageing factor AF is raised in a suitable manner. This increment can be dependent for example on the current air/fuel ratio, on the temperature of the NOx storage catalytic converter, and on the current value of the ageing factor AF.

If lean operation of the internal combustion engine is again permissible after a desulphatisation operation has taken place on the basis of the value of the ageing factor AF, the correction of the increased ageing factor AF which results from desulphatisation is performed in the next stages of ageing

detection. If during this process the storage capacity of the NOx storage catalytic converter 18 is found not to have risen by a required amount as a result of desulphatisation, it is assumed that the NOx storage capacity of the NOx storage catalytic converter has fallen irreversibly below a minimum value. From this point in time, lean operation is prohibited and no further desulphatisation is requested. The method is continued with the method steps S6-S8 described previously.

Fig. 4 shows the progression of the ageing factor AF over the flow distance of the NOx storage catalytic converter and the operational strategy derived from this during lean operation of the internal combustion engine. In addition to the individual threshold values SW1-SW3, a value AFN is entered on the ordinate in this diagram which indicates the ageing factor of an as-new NOx storage catalytic converter. The associated points in time t1-t3 at which the measures described above are initiated are entered for the individual threshold values SW1-SW3.

Claims

1. Method for operating and checking of the activity of a NOx storage catalytic converter (18) located in an exhaust gas port (16) of an internal combustion engine (10),

- which stores NOx contained in the exhaust gas during a storage phase and, when a predefined loading has been reached, converts stored NOx during a regeneration phase through the addition of a reducing agent in order to empty the NOx storage catalytic converter (18), and
- the current storage capacity of the NOx storage catalytic converter (18) is calculated from the stored quantity of NOx and the associated loading level of the NOx storage catalytic converter (18) by using the signal from a sensor (21) located downstream of the NOx storage catalytic converter (18) which detects the concentration of at least one exhaust gas component,
- from this is derived an ageing factor (AF) for the NOx storage catalytic converter (18), which defines the current storage capacity of the NOx storage catalytic converter (18) after it has been reduced by external influences, and
- the ageing factor (AF) is compared in succession with multiple threshold values (SW1-SW3) of differing levels, where the level of the threshold values (SW1-SW3) decreases as the flow distance of the NOx storage catalytic converter increases, and
- in the event of certain threshold values (SW1-SW3) not being reached, different operational strategies are initiated for the NOx storage catalytic converter (18) and/or the internal combustion engine (10).

2. Method in accordance with Claim 1, characterised in that the ageing factor (AF) is compared with a first threshold value (SW1) and, if the first threshold

value (SW1) is not reached, a desulphatisation phase is requested for the NOx storage catalytic converter (18).

3. Method in accordance with Claim 2, characterised in that after a desulphatisation phase has been requested through temperature increase, a desulphatising atmosphere is created and the value for the ageing factor (AF) is raised by means of an incremental value during the desulphatisation phase.

4. Method in accordance with Claim 3, characterised in that the definition of the incremental value for the ageing factor (AF) is dependent on at least one of the following variables: temperature of the NOx storage catalytic converter (18), air/fuel ratio, current value of the ageing factor (AF).

5. Method in accordance with Claim 2, characterised in that the ageing factor (AF) is compared with a second threshold value (SW2), lower compared with the first threshold value (SW1), if the requested desulphatisation phase for the NOx storage catalytic converter (18) cannot be carried out because the temperature level is too low and, if the second threshold value (SW2) is not reached, an increase in exhaust gas temperature is requested.

6. Method in accordance with Claim 5, characterised in that the ageing factor (AF) is compared with a third threshold value (SW3), lower compared with the second threshold value (SW2), if the temperature level for desulphatisation is not reached and, if the third threshold value (SW3) is not reached, lean operation of the internal combustion engine (10) is no longer permitted.

7. Method in accordance with Claim 6, characterised in that if the third threshold value (SW3) is not reached, a malfunction entry is made in a malfunction memory (25) of a memory unit (24) which is associated with a control unit (23) serving to control the internal combustion engine (10).

8. Method in accordance with Claim 6, characterised in that if the third threshold value (SW3) is not reached, the NOx storage catalytic converter (18) is operated as a three-way catalytic converter.

9. Method in accordance with Claim 6, characterised in that if the third threshold value (SW3) is not reached, the internal combustion engine is operated with a stoichiometric air/fuel mixture.

10. Method in accordance with Claims 6 and 8, characterised in that if the third threshold value (SW3) is not reached, the oxygen storage capability of the NOx storage catalytic converter (18) is determined by means of the output signals from the sensors (19,21) located upstream and downstream of the NOx storage catalytic converter (18), is compared with a prespecified threshold value (SW0) and, if the threshold value (SW0) is not reached, the NOx storage catalytic converter (18) is considered to be no longer operable.

11. Method in accordance with Claim 10, characterised in that a malfunction indication lamp (26) is illuminated to indicate that the NOx storage catalytic converter (18) is considered to be no longer operable.

12. Method in accordance with Claim 1, characterised in that an oxygen sensor which registers the oxygen concentration is used as the sensor (21).

13. Method in accordance with Claim 1, characterised in that a NOx sensor which registers the nitrogen oxide concentration is used as the sensor (21).

14. Method in accordance with Claim 1, characterised in that an HC sensor which registers the hydrocarbon concentration is used as the sensor (21).

Application No: GB 9925994.7
Claims searched: 1-14
Examiner: Jeremy Philpott
Date of search: 11 April 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): B1W [WAX, WD, WX]

Int Cl (Ed.7): B01D: 53/94, F01N: 3/08, F02D: 41/02

Other: On-line: WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2307311 A	(Mercedes Benz AG) whole document & Figures	
X, E	EP 0972927 A2	(Denso Corp.) whole document & Figures	1 at least
A, P	EP 0950801 A1	(Degussa-Hüls AG) whole document & Figures	
X	EP 0928890 A2	(Degussa-Hüls AG) whole document & Figures	1 at least
X	US 5778666	(Ford Global Technologies Inc.) whole document & Figures	1 at least
X	US 5771685	(Ford Global Technologies Inc.) whole document & Figures	1 at least
X	US 5693877	(Hitachi Ltd.) whole document & Figures	1 at least
A	US 5317868	(Siemens AG) whole document & Figures	

X	Document indicating lack of novelty or inventive step
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.
&	Member of the same patent family
A	Document indicating technological background and/or state of the art.
P	Document published on or after the declared priority date but before the filing date of this invention.
E	Patent document published on or after, but with priority date earlier than, the filing date of this application.